Using Propulsion System for Loss of Control Prevention and Mitigation

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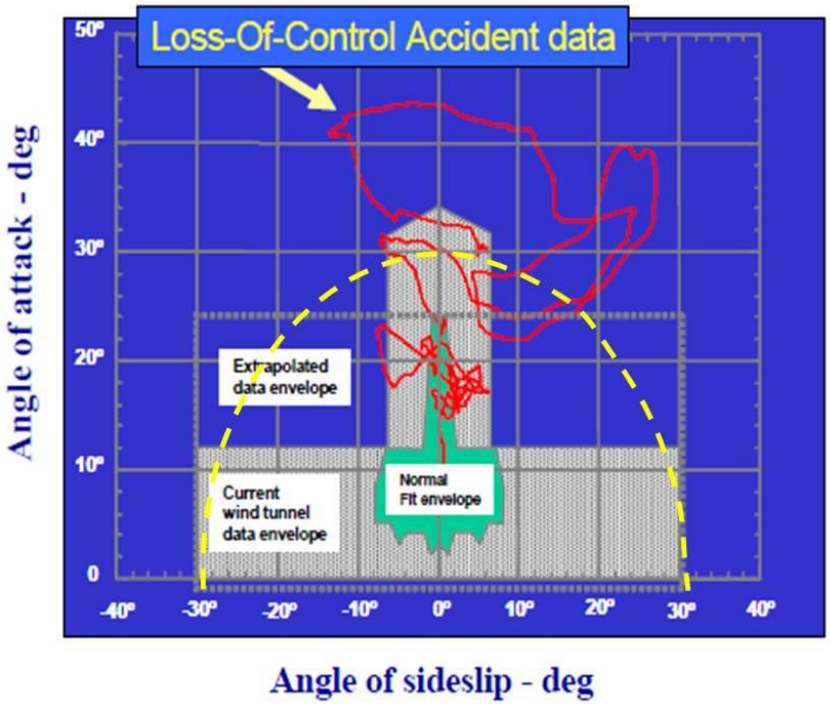
Use of Propulsion for Envelope Protection

- The engines are very powerful actuators for augmenting the flight control system
- They have a wider operating envelope (altitude, angle of sideslip, and angle of attack) than traditional control surfaces of the aircraft
- The pylons used to attach the engines to the plane are structurally very strong to accommodate the propulsion system as a flight control effector

Authority of the engine compared to aircraft flight envelope

- The yellow arc represents the engine's operational range in terms of angle of attack and sideslip
- To investigate envelope protection schemes that utilize the propulsion system, we need good models that cover this operating region



Pilot-in-the-loop testing capability
Flight Simulator

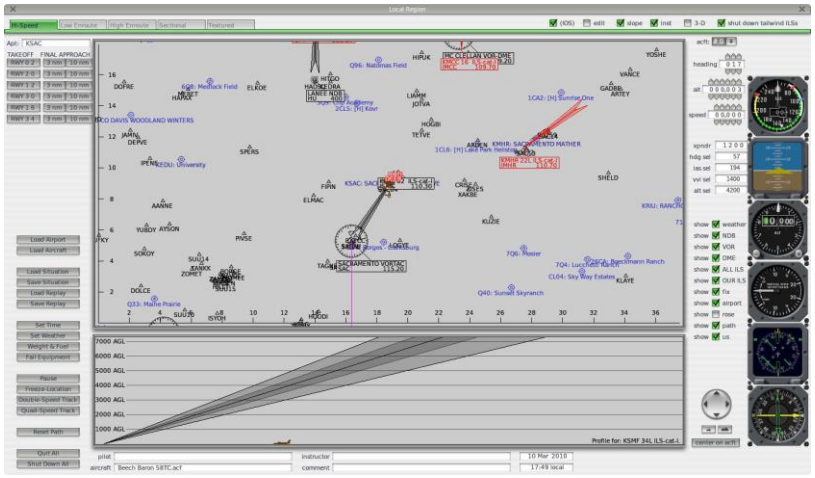
- This is our old system
- It had two throttles, rudder pedals, and a side-stick

Pilot-in-the-loop testing capability
Flight Simulator

- This is our new system
- Installed in March
- FAA certified trainer for built-in aircraft models (Cessna Skyhawk, Citation, etc.)

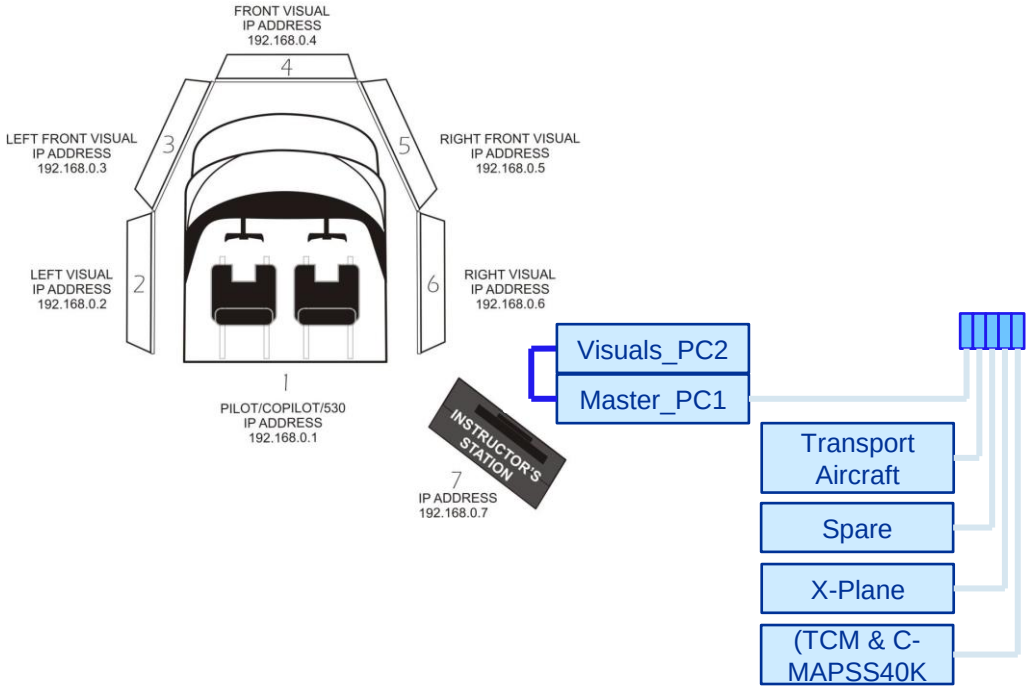
Pilot-in-the-loop testing capability
Flight Simulator

- It has a motion base,
- a wrap-around high-definition visual display,
- a Garmin 530 GPS, and
- an Instructor's station that enables setting weather conditions (wind, cloud layers, temperature, precipitation), and aircraft configuration (available fuel, weight, center of gravity)



Pilot-in-the-loop testing capability
Flight Simulator

- Software is X-Plane based, which allows modification and interfacing with external systems
- Using the hooks in X-Plane, the built-in aircraft models can be replaced by research simulations



Pilot-in-the-loop testing capability
Flight Simulator

- Six programmable overhead switches
- Cockpit instrumentation and throttles can be customized for different aircraft

Transport Class Model (TCM)

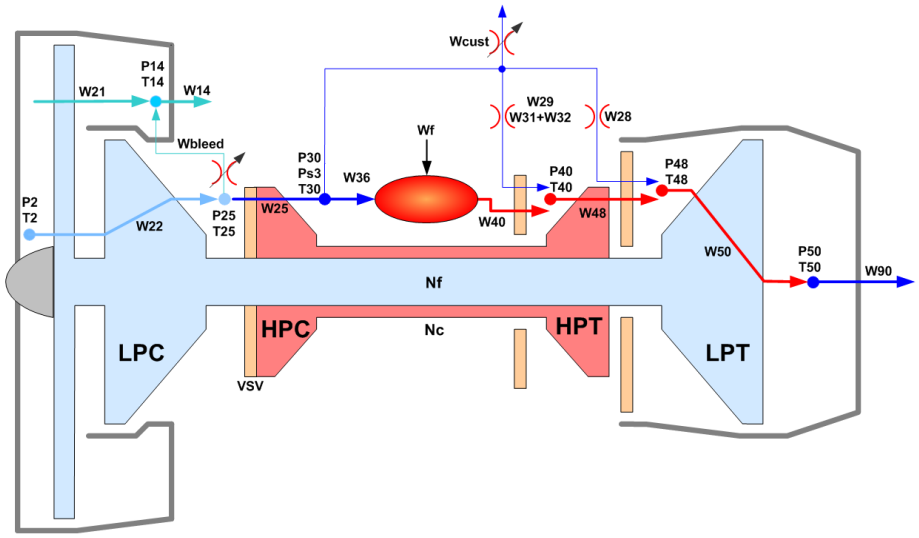
- Requires two 40,000 lb thrust class engines
- Transport Class Model (TCM) is a NASA-developed simulation of a 200 passenger commercial jet aircraft
- It is a full size version of the subscale Generic Transport Model (GTM), which is similar to Airstar, the NASA Langley testbed

Transport Simulation

- Large, four engine transport aircraft
- Requires four 40,000 lb thrust class engines
- Highly realistic behavior
- Detailed, complex flight control system

Commercial Modular Aero-Propulsion System Simulation (C-MAPSS40k)

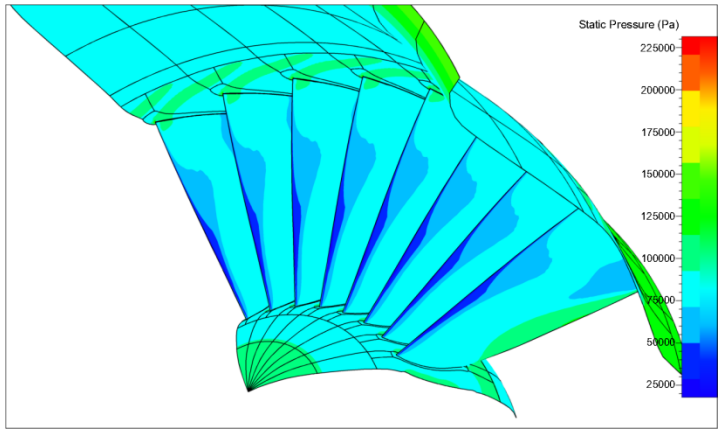
- 40,000 lb thrust class engine
- Runs in real time
- Realistic controller
- Actuators are fuel valve, variable stator vanes (VSV), variable bleed valve (VBV)
- Realistic behavior, including off-nominal



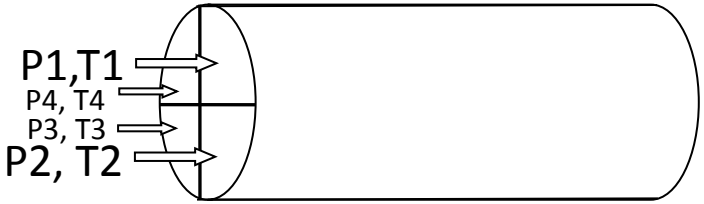
Updates to C-MAPSS40k
High Angle of Attack Modeling

- Original approach used a parallel compressor model to simulate inlet distortion.
- The results were calibrated using sectored CFD

Single flow path



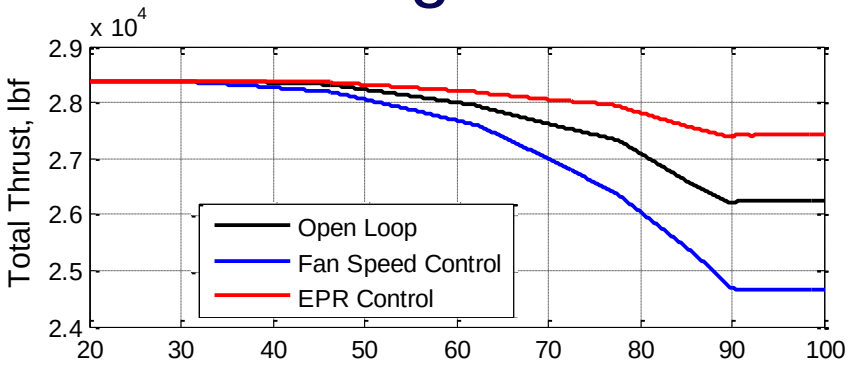
Partial-annulus inlet/fan model displaying static pressure contours calculated at zero AOA



Parallel Compressor Approach
Multiple interacting flow paths

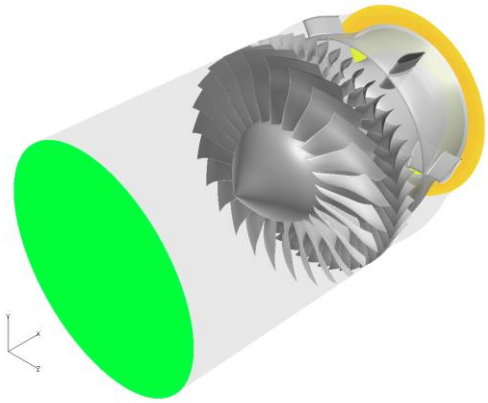
Updates to C-MAPSS40k High Angle of Attack Modeling

- For simplification and real-time operation, scale factors for variables of interest were determined so that C-MAPSS40k output matches parallel compressor results



Response of total thrust using various controllers to increasing AOA (0° to 21 ° from 30 to 90 seconds)

- Currently, a full annulus CFD modeling approach is being used to validate sectored CFD results, as well as add fidelity and ability to reach a larger AOA

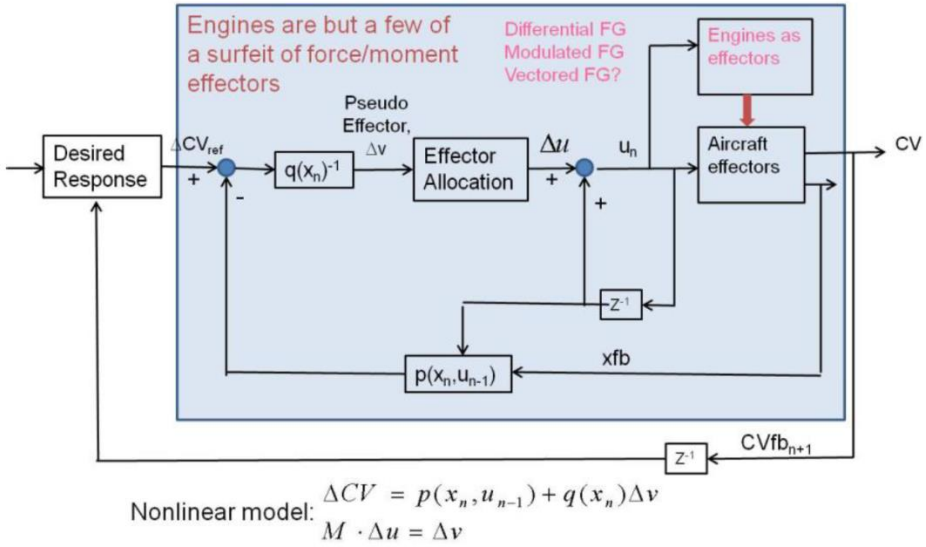


Full annulus CFD approach to modeling effect of inlet distortion

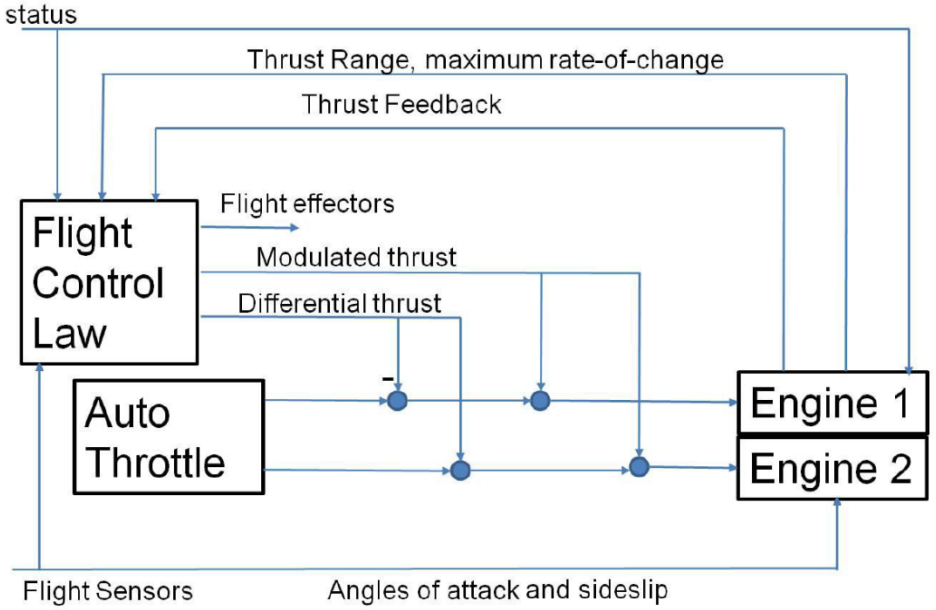
Integrated Flight and Propulsion Control (IFPC) Contract with Pratt & Whitney

- Developed architecture to integrate propulsion system with flight control to prevent or mitigate selected loss-of-control scenarios.
- Uses Dynamic Inversion to match the desired response
- Propulsion is only utilized for maneuvering in abnormal situations

Addition of engines to typical dynamic inversion flight control law

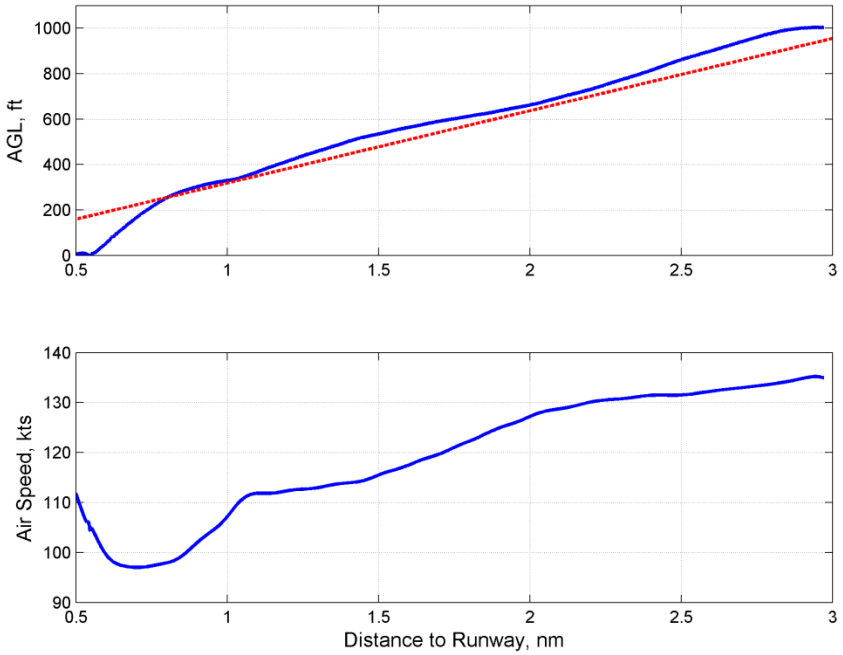


High Level Integrated Flight and Propulsion Control



Research Scenarios

- Have started to look at case of Asiana 214
  - Too low and too slow, hit just short of runway, hull loss, casualties
- Preliminary work shows promise
- Plan to have more details at AIAA SciTech Conference, January 13-17, 2014, National Harbor, MD



Summary

- New flight simulator enables better pilot interaction with the airframe and engine simulations than previously possible
- High AOA modifications to C-MAPSS40k allow more realistic modeling of behavior in specific loss of control situations
- Investigating IFPC and other potential approaches to envelope protection using the propulsion system

Thank you